Naval Submarine Medical Research Laboratory

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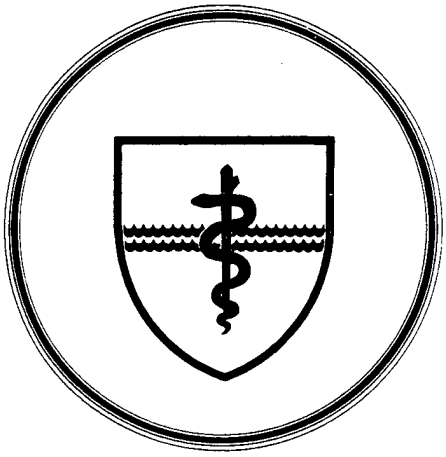

U.S. Navy Color Vision Standards Revisited

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Released by
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U.S. NAVY COLOR VISION STANDARDS REVISITED

Kevin V. Laxar, PhD

Naval Submarine Medical Research Laboratory
Memo Report 98-01

Naval Medical Research and Development Command
Research Work Unit No. 61153.4101.003.5502

Approved and Released by:

M. T. Wooster, CAPT, MSC, USN
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SUMMARY PAGE

THE PROBLEM

Questions have been raised at BUMED 21 concerning the need for color vision requirements, the granting of waivers for color vision deficiency, the evaluation of "functional color vision" through field tests, and the interpretation of sections of the U.S. Navy's *Manual of the Medical Department* pertaining to color perception testing. Most recently these issues have been brought up in regard to Nuclear Field Duty personnel, but the questions have also come up over the years in the context of line officers, submariners, and other ratings.

FINDINGS

The basic facts of color vision deficiency and its testing are reviewed, including the rationale for the design of the Farnsworth Lantern (FALANT), the standard Navy test for color perception. Also reviewed are studies of the performance of various types and degrees of color vision defectives and previous considerations of Navy color vision standards. It is concluded that personnel who do not pass the FALANT should not be generally accepted for positions that involve color vision tasks.

APPLICATION

A version of this report was transmitted to BUMED 21 on 21 Jan 1998 in response to questions regarding the color vision requirements of Nuclear Field Duty personnel. This information, however, is also applicable to any Navy facility that tests color vision or is concerned with color vision requirements.

ADMINISTRATIVE INFORMATION

This study was conducted at the Naval Submarine Medical Research Laboratory under Naval Medical Research and Development Command Research Work Unit No. 61153.4101.003.5502, Simultaneous and Successive Color Contrast: Investigations of the Red-Green and Blue-Yellow Systems and Refinement of the Opponent Model. The manuscript was submitted for review on 08 April 1998, approved for publication on 27 April 1998, and designated as NSMRL Memo Report No. 98-01. The opinions or assertions contained herein are the private ones of the author and are not to be construed as official or reflecting the views of the Department of the Navy, the Department of Defense, or the United States Government.

Abstract

Following a visit to Naval Reactors, BUMED 21 requested from the Naval Submarine Medical Research Laboratory information on evaluating "functional color vision" for nuclear field duty personnel. Color vision standards for other positions in the Navy have been considered in the past and are applicable to nuclear field duty and other tasks that require color vision. MANMED states that the Farnsworth Lantern (FALANT) is the standard Navy color perception test. It passes color vision normals and 30% of color vision defectives who have been shown to have sufficient color vision to perform required color tasks accurately. Prior research and deliberations have concluded that any relaxation of the requirement to pass the FALANT is strongly not advisable. MANMED also states that waivers will be considered for those failing the FALANT who can demonstrate a functional ability to discern color associated with their work environment. Reasons why it is strongly not advisable to consider such waivers are discussed. BUMED 21 has stated that the pseudo-isochromatic plate (PIP) test is typically used as a functional test of color vision. With proper administration, however, only color vision normals will pass the PIP test, and anyone who fails the FALANT will fail the PIP. The PIP test, therefore, is a useful though more stringent test of color vision than the FALANT, but it is not useful as a functional test of color vision for persons who fail the FALANT. It is concluded that personnel who do not pass the FALANT should not be generally accepted for positions that involve color vision tasks.

U.S. Navy Color Vision Standards Revisited

During a visit by BUMED to Naval Reactors in September, 1997, questions were raised concerning the need for color vision requirements, the granting of waivers for color vision deficiency, the evaluation of "functional color vision" through field tests, and the interpretation of sections of the U.S. Navy's *Manual of the Medical Department* (MANMED) pertaining to color perception (color vision) testing. Pursuant to this visit, a request was made by BUMED 21 to the Naval Submarine Medical Research Laboratory (NSMRL) for information on evaluating "functional color vision" for nuclear field duty personnel (BUMED 21, 1998). Such questions have come up over the years in the context of line officers, submariners, and other ratings, and have been addressed before. Although MANMED specifies the requirements and tests for color perception, it does not discuss the fundamental theories and issues of color vision deficiency or color vision testing. The present report, a version of which was transmitted to BUMED 21 (Commanding Officer, NSMRL, 1998), reviews color vision deficiency, its testing, and color vision standards in the U.S. Navy, and restates the need for compliance with MANMED.

A Brief Review of Facts about Color Vision Deficiency

The term "color blind" is somewhat of a misnomer. People with a color vision deficiency (color defectives) are not truly color blind. They can distinguish some colors, but not as many as persons with normal color vision. Often their color judgments are based on brightness rather than hue, and on their learning of what color name to give particular objects. About 10% of men (and 0.5% of women) are color defectives.

There are different degrees of color vision deficiency, varying from mild to severe. Of those who have a color vision defect, 30% have a mild defect, 20% are moderate, and 50% are severe or dichromatic (who see color in terms of two, rather than three, cone receptor types) (Paulson, 1966). (Due to the extremely small percentage of women with color vision deficiency, the masculine reference will generally be used here).

The two common types of color defectives are protans (red defectives) and deutans (green defectives). Approximately one-third of color defectives are protans and two-thirds are deutans (Paulson, 1966). Both have trouble distinguishing certain reds from certain greens and base much of their color judgment on a yellow-blue dimension and on brightness. Protans have an additional problem of a reduced luminosity function, that is, stimuli at the red end of the spectrum look very dark to them. (A third type, the tritan (blue defective) confuses blue and yellow but has no problem with reds and greens. This type is so rare as to make testing for it not worthwhile and will not be discussed here.)

Testing and Classifying Color Defectives

NSMRL uses a standard Navy test battery (Farnsworth, Sperling, & Kimble, 1949) to determine the type and degree of color vision defect. In its simplest form, it consists of three tests: a selected version of pseudo-isochromatic plates (PIP), the Farnsworth Lantern (FALANT), and the Farnsworth Dichotomous-15 button test (D-15). Each of these tests has specific conditions for proper administration. When all the conditions required for each test's proper administration are strictly adhered to, the tests are extremely reliable and accurate and

yield the following results. The PIP, the most stringent test, passes normals and fails all color defectives. The FALANT passes normals and those with a mild color defect. Anyone who fails the FALANT has either a moderate or severe defect. The D-15 passes normals, "milds," and "moderates," and fails those with a severe defect. This classification scheme is shown in Table 1. For the present purposes, those classified as mild and moderate are anomalous trichromats and those classified as severe include both anomalous trichromats and dichromats.

Table 1. *Classification scheme for NSMRL Color Vision Test Battery.*

Classification	Test		
	PIP	FALANT	D-15
Normal	Pass	Pass	Pass
Mild	**Fail**	Pass	Pass
Moderate	**Fail**	**Fail**	Pass
Severe	**Fail**	**Fail**	**Fail**

Design and Validity of the FALANT

The FALANT was developed at NSMRL by CDR Dean Farnsworth, and has been the standard Navy test for color perception since 1954. It was designed to make that additional 3% of men who are mildly color defective available for jobs that require good color vision. Farnsworth had conducted a series of tests using various types and degrees of color defectives doing shipboard tasks requiring color vision. The tests showed that the mild defectives were as good as normals for performing color vision tasks, but that moderates and severes made many errors. Additional studies have reaffirmed the reliability and diagnosticity of the FALANT (Laxar, 1967; Paulson, 1966, 1982).

That the FALANT is an appropriate color vision screening device was more recently validated in a study to determine chromaticity specifications for color coded console lights (Paulson, 1974). Forty normals and 48 classified color defectives categorized 408 colored lights as either blue, red, green, yellow, or white. The results showed that (1) the mild color defectives perform about as well as normals, (2) moderate color defectives make considerably more errors than milds and normals, and (3) severe defectives make even more errors than moderates.

"Functional Color Vision" Tests

At least eight MANMED articles list color perception requirements for particular duties. They all specify passing the Farnsworth Lantern for qualification, and several state that waiver will be considered for personnel who can demonstrate a functional ability to discern color associated with their work environment. Information from BUMED 21 (1997) indicates that in

practice "typically, the PIP is used to further evaluate 'functional color vision'." The classification scheme described above, however, shows that anyone who fails the FALANT will also fail the PIP if the tests are properly administered. Thus, the PIP is not appropriate as a further test for evaluating 'functional color vision' because it will always fail the person who fails the FALANT.

A field test for personnel failing the PIP or FALANT was discussed during the visit of BUMED 21 to Naval Reactors (1997). Possible "field tests" of "functional color vision" capability were considered, such as correctly naming colors in an illuminated panel display, on a CRT screen, or in a bundle of colored wires. "Field tests" such as these must be strictly avoided, for a number of reasons. While they may have some momentary face validity, they are necessarily unreliable. The test conditions are not standardized, the subject may be given too much time to make his decision, or the tester may relax his pass/fail criterion. The colors on displays, wires, and the like can vary widely, so that while a subject may be able to correctly identify the colors at a particular time and place, he may not be able to do so elsewhere. The color of wires may be easily distinguishable in relaxed conditions under good lighting, but impossible for a color defective under reduced illumination or under the stress of an emergency. Red, yellow, and green may be distinguishable on one CRT screen but not on another, due to lack of standardization of the colors used and the wide variability in color monitors.

Relaxing the Color Vision Standards

BUMED 21 (1997) questioned whether to consider the use of the D-15 test as a field test for functional color vision. As noted above, the D-15 fails only severe color defectives, but passes normals, milds, and moderates. On the average, 95% of the male population will pass the D-15, with 2% being moderately defective. A problem with the use of the D-15 as a field test is that it may be allowing these moderate color vision defective personnel to hold positions in which errors in color judgment might be made. The following quote is from Farnsworth (1957) in an address to industry personnel:

> A moderately color defective [person] ... must never be placed in a position in which a failure of color judgment would jeopardize persons or property. He can distinguish code colors with reliability only when the colors are clean, unobscured, in good light, reasonably large in size, and when he is not hurried or distracted. This provides the opportunity to place the moderate defective in most factory operations [which] are usually done under good lighting; the colors are unsoiled, the job is repetitive and a mistake is remediable.

Field tests made up by a supervisor, however, could place severe defectives in situations that could cause danger. To quote again from Farnsworth (1957):

> The severe color defective must never be placed in a situation where color discrimination is important. Even though he can prove his ability at your desk to make some color distinctions, it must be remembered that, to him, these constitute the equivalent of 'fine discriminations' to the normal; gross color differences will pass unnoticed in the

complexities of the job situation and fail to warn him of the cues upon which efficiency or safety depend.

Therefore, in certain situations, the D-15 could be used as a screening test, thus admitting certain moderate defectives to some jobs. See the important caveats in the Conclusion section, however. One issue with the administration of this test is that, like the PIP test, in order to be valid, it must be administered under simulated daylight Illuminant C. At present, the D-15, and likely the daylight lamp, are not readily available at the usual testing sites. The FALANT, on the other hand, is faster and easier to administer and is designed to be given in normal room illumination.

Rather than using the D-15, the possibility has been examined of using a higher error cutoff score for passing the FALANT. The current criterion is an average of one wrong or less over two runs of all nine pairs of lights. The FALANT, however, draws a fine line between normals and the mildly defective and those with greater defects. In two studies (Laxar, 1967; Paulson, 1966), it was shown that even raising the cutoff score to an average of 1.5 errors would pass some severe defectives, an unacceptable result.

The question of changing the standards for color vision has come up in the past. The most recent one known to NSMRL was a request for evaluation by CNO (Ser 291C/185431 dated 08 Dec 1975) in regard to officer applicants for training in nuclear submarines. This request led NSMRL to: (a) hold two Color Perception Standards Conferences; (b) conduct a color vision task analysis aboard submarines; (c) evaluate the performance aboard submarines of several color defectives with waivers; (d) conduct experiments with color defectives identifying colored lights at sea; (e) have changes made in MANMED; and (f) publish a letter report titled "Summary Report of Research on Naval Color Vision Standards" (NSMRL-00 3900, Ser: 346 dtd 7 Nov 1979). This letter report is contained in Appendix A.

Conclusion

It is the opinion of the Naval Submarine Medical Research Laboratory that the guidelines for the employment of color vision defective personnel stated in the Summary Report in Appendix A are satisfactory and appropriate for the utilization of Naval Reactor Personnel and other positions that involve color vision tasks. We feel that the conclusions reached at that time are just as valid today. This report states the following:

> A major conclusion of the [two color vision] conferences was that judging colored lights at sea was the most critical color-related task that Naval Officers perform. [Two field experiments showed that,] on the average, men with moderate or worse degrees of color vision defect are incapable of correctly judging lights at sea. Categories of color defective men additional to those that pass the FALANT should not be generally accepted.
>
> When the supply of men is adequate, color vision standards should be strictly adhered to; since color defectives can represent a hazard to their ship, this is clearly in the

best interests of the Navy.

In times of critical need for specific specialties, waivers can be considered for men of exceptional ability and motivation. In this case, however, specific precautions are essential.

(1) Color vision standards for men with a protan defect should not be waivered [due to their being] insensitive to red lights.

(2) Any color defective accepted for Naval duty on a waiver should be thoroughly briefed on the nature of his defect, on the color confusions that he is likely to make, and on the fact that he should never rely on his own judgments in a situation where color differentiation is important. Furthermore, his Commanding Officer should be briefed on the problem and should not assign him, alone, to duties where color discrimination is necessary.

In conclusion, in times of critical need, some men could be utilized for duty via waiver of color vision requirements as long as the above noted precautions are taken. However, since some small risk still occurs and since these precautions require implementation, unless the need is critical we do not recommend waivers.

Further details can be found in Appendix A. We wish to emphasize that, for maximum safety, in view of the increased use of color coding in all electronic displays, the most conservative approach should be used whenever possible.

ACKNOWLEDGMENT

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APPENDIX A

Letter report titled "Summary Report of Research on Naval Color Vision Standards" (Enclosure to NSMRL-00 3900, Ser: 346 dtd 7 Nov 1979).

SUMMARY REPORT OF RESEARCH ON NAVAL COLOR VISION STANDARDS

1. Standards for entrance into Naval Submarine School require normal or near-normal color vision for officers and most ratings. The final criterion is ability to pass the Farnsworth Lantern, a test specifically designed to pass both normal and mildly color defective individuals. Since approximately 7% of American males cannot meet this criterion, a research project was started in October 1976 to analyze the tasks involving color aboard submarines with the hope that perhaps men with moderate degrees of defect might be found capable of performing the tasks.

This research project on submariners was quickly expanded to include all Naval line officers, following two conferences on Color Vision Standards in March and August, 1976. A major conclusion of the conferences was that judging colored lights at sea was the most crucial color-related task that Naval officers perform. Consequently, an experiment was performed at Annapolis on the ability of color defective men, who were carefully categorized as to type and degree of defect, to judge the colors of lights at sea. The result, that men of moderate and severe disability did not perform adequately, was reported to BUMED in November, 1977, with the statement that no recommendations could be made to lower standards at that time. Since then, the experiment has been repeated in Groton, CT, to test the reliability of this finding. The second experiment completely upheld the results of the first: on the average, men with moderate or worse degrees of color vision defect are incapable of correctly judging lights at sea. Since this is a crucial task for line officers, it is unfortunately clear that additional categories of color defective men should not be generally accepted.

2. Despite this clear-cut result, staff of the Submarine Medical Research Laboratory realize that the need for qualified Naval personnel can sometimes become critical. Consequently, we have reviewed and analyzed the color tasks aboard ship (e.g., color coding used for valve handles, for indicator lights on display panels, for various medical tasks performed by hospital corpsmen, and for electronic gear), and make the following suggestions as to policy concerning color vision standards.

a. In times when the supply of men is adequate, color vision standards should be strictly adhered to; since color defectives can represent a hazard to their ship, this is clearly in the best interests of the Navy.

b. In times of <u>critical</u> need for specific specialties, waivers can be considered for men of exceptional ability and motivation. In this case, however, specific precautions are essential.

(1) Color vision standards for men with a <u>protan</u> type of defect should not be waivered. Protans perform very poorly judging lights at sea. They are very insensitive to red lights and, consequently, often fail to see a light that is clearly visible to color normals or deutans. Their insensitivity to red also makes it impossible to work in red lighted areas, such as submarine

Two-thirds of the men currently disqualified for Naval duties requiring good color vision are deutans, the other third, protans. Differentiation of red/green color defectives into the two categories of protan and deutan is not difficult. It is commonly done in universities, hospitals, and in the offices of some ophthalmologists and optometrists. Nonetheless, the testing equipment required is generally not available in most Naval Regional Medical Centers and implementation of this suggestion would require either that the men be tested where such diagnosis is possible or that equipment be made available to the regional centers.

(2) Any color defective accepted for Naval duty on a waiver should be thoroughly briefed on the nature of his defect, on the color confusions that he is likely to make, and on the fact that he should never rely on his own judgments in a situation where color differentiation is important. Furthermore, his Commanding Officer should be briefed on the problem and should not assign him, alone, to duties where color discrimination is necessary (for example, judging the colors of running lights on other ships).

During the past three to four years, three men have served on submarines under a waiver of the color vision requirement including the above stipulations. The men reported their experiences to us. In addition, the Commanding Officer and other supervisors reported that the color vision deficiency did not degrade the performance of the color defectives aboard the ship. The color defectives themselves, however, did report occasional difficulty in correctly identifying navigational lights on initial observation, but stated that they exercised extreme diligence in keeping their eyes on the lights as the target neared so that corrective action could be taken prior to contact closing. It is felt that a major reason for the lack of severe problems lies in the fact that the men were aware of their special status. It cannot be emphasized too strongly that the man who admits his defect, realizes he cannot distinguish colors and seeks help does not represent the same hazard as the man who hides his defect and attempts to perform normally.

3. In conclusion, in times of critical need, some men could be utilized for duty via waiver of color vision requirements as long as the above noted precautions are taken. However, since some small risk still occurs and since these precautions require implementation, unless the need is critical we do not recommend waivers.

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Following a visit to Naval Reactors, BUMED-21 requested from the Naval Submarine Medical Research Laboratory information on evaluating "functional color vision" for nuclear field duty personnel. Color vision standards for other positions in the Navy have been considered in the past and are applicable to nuclear field duty and other tasks that require color vision. MANMED states that the Farnsworth Lantern (FALANT) is the standard Navy color perception test. It passes color vision normals and 30% of color vision defectives who have been shown to have sufficient color vision to perform required color tasks accurately. Prior research and deliberations have concluded that any relaxation of the requirement to pass the FALANT Is strongly not advisable. MANMED also states that waivers will be considered for those

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